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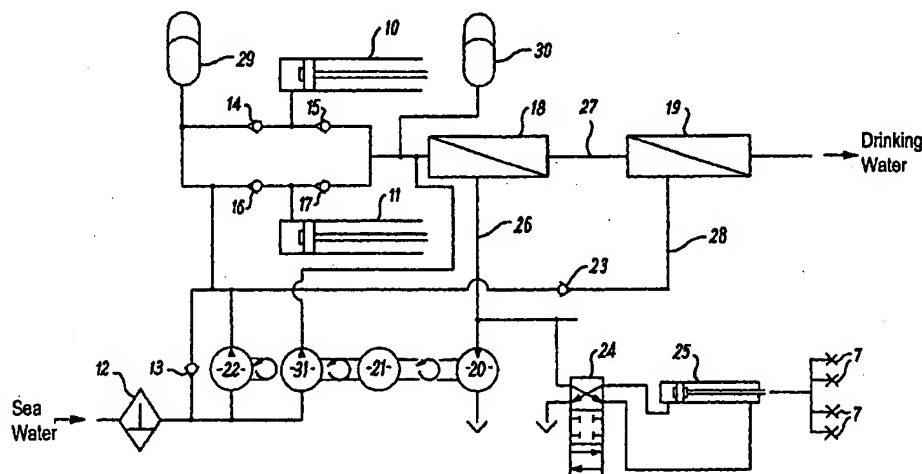
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(54) Title: DESALINATION DEVICE



(57) Abstract: Apparatus and a method for the desalination of a liquid are described. In particular the apparatus and method are suitable for the desalination of water so as to provide a means for supplying potable water from an impure source. The described desalination device (1) comprises a water engine (3) and a reverse osmosis unit (4). The liquid to be desalinated is directed to the hydraulic rams (10, 11) of a water engine (3). Thus when located within a body of water, the operation of the water engine (3) increases the pressure of the liquid to a sufficient level that desalination can take place within the reverse osmosis unit (4). The desalination device (1) is particularly suited for incorporation with a body of water that exhibits tides since this provides a renewable source of energy for the operation of the water engine (3).

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

1 Desalination Device

2

3 This invention relates to apparatus and a method for the
4 desalination of a liquid. In particular it relates to
5 the desalination of water so as to provide a means for
6 supplying potable water from an impure source. Within
7 the described apparatus and method the required pressure
8 for the desalination process is provided by a water
9 engine that is driven by its interaction with a body of
10 water.

11

12 Desalination of sea water, so as to be suitable for human
13 consumption, can be achieved through a reverse osmosis
14 process as is well known to those skilled in the art.
15 Such processes allow a water supply to be installed, for
16 instance, in remote areas where there is insufficient
17 water for human consumption or crop irrigation.

18

19 Reverse osmosis refers to the process of passing a liquid
20 through a membrane in order to remove any salts suspended
21 within the liquid and the removal of certain bacteria and
22 viruses. Generally the process requires the sea water to
23 be put under sufficient pressure such that it is capable
24 of being forced through the membrane.

1 There are a number of methods and apparatus described in
2 the Prior Art for the desalination of sea water.
3 Typically, the osmotic pressure of sea water is around 28
4 bar (28×10^5 Pa) for a 3.5% salt solution. Therefore, in
5 order to operate a reverse osmosis desalination system a
6 pressure of 70 bar (70×10^5 Pa) is typically used and
7 electrical pumps are generally employed to provide this
8 pressure. Filter membranes tend to become clogged up
9 during operation. To prevent this sea water is passed
10 over the membrane so as to flush the clogging
11 contaminants. Therefore, to keep the membrane from
12 becoming clogged the recovery amount through the reverse
13 osmosis filter for sea water at 35000 mg/l salt solution
14 is typically limited to around 25%. Thus only 25% of the
15 high pressure water is yielded as permeate while the
16 other 75% is ejected as brine concentrate. A theoretical
17 minimum energy requirement for the desalination of sea
18 water is calculated to be around 0.75 kW/hr per cubic
19 meter of water produced, regardless of the technique
20 used.

21
22 The most widely used form of reverse osmosis filter is a
23 spiral wound cartridge. Typical reverse osmosis systems
24 employing such filters require a 4kW pump capacity per
25 cubic meter of water produced. This figure includes the
26 use of turbine pumps to recover energy from the 75% of
27 the high pressure water that passes through the filter.
28 A commercial system providing 400 tonnes of water per day
29 therefore requires a 375kW pump motor that needs a
30 significant electrical supply.

31
32 Therefore, to use existing reverse osmosis technology in
33 remote areas, or areas with insufficient or expensive
34 electrical supplies, can be difficult to achieve without

1 significant upgrading of the electrical supply system.
2 In the case of islands connected by cables to a mainland
3 this may be impractical due to cost. The use of a local
4 renewable energy resource would obviously help to
5 alleviate this problem.

6

7 It is known to those skilled in the art that wind, solar
8 and wave energy are all potential candidates for local
9 renewable energy sources, however these techniques all
10 depend on an intermittent source. A more preferable
11 source is the use of tidal energy since this provides
12 energy for regular periods every day throughout the year,
13 and so ensures a constant supply of desalinated water.

14

15 UK Patent No. GB 1,130,107 teaches of apparatus for the
16 desalination of sea water using reverse osmosis and tidal
17 energy. The apparatus comprises a buoyant vessel
18 attached to the seabed, wherein the vessel is allowed to
19 rise with the incoming tide. As the vessel rises a
20 piston located in a cylinder, anchored to the seabed,
21 simultaneously compresses sea water and forces it through
22 a reverse osmosis membrane. Unfortunately this technique
23 only extracts energy on the rising phase of the tide.
24 Furthermore no means of flushing the surface of the
25 filter membrane is provided hence the system gradually
26 degrades as the membrane becomes clogged. During the
27 falling phase of the tide the associated hydrostatic
28 pressure is employed to empty the desalinated water out
29 of the area above the piston. However, no account is
30 made for the normal osmosis effect that would result in
31 the emptied water being returned to the salt solution
32 located below the piston.

33

1 UK Patent No. GB 1,141,138 and European Patent
2 Application No. EP 1,214,137 teach of sea water driven
3 desalination apparatus that employ hydrostatic pressure
4 in order to provide the required force to drive the sea
5 water through a reverse osmosis membrane. Such apparatus
6 require the reverse osmosis filter to be mounted in a
7 vessel submerged at a sufficient depth. Therefore, these
8 designs result in the construction of very expensive
9 offshore installations in order to get the membranes to
10 the required depths. A further disadvantage is that the
11 fresh water produced must then be pumped back to the
12 surface and thereafter transported to its point of use.
13 In addition neither document teaches of a mechanism for
14 flushing the surface of the filter membranes and so a
15 steady degradation in the performance of the apparatus
16 results.

17

18 PCT Application WO 99/28622 teaches of a wave-powered
19 prime mover that comprises a pair of pontoons connected
20 to a central inertial barge. Each pontoon is pivotally
21 movable by ocean swell or waves relative to the barge. A
22 pump connected between each pontoon and the barge
23 converts the motion of the pontoon into water pressure
24 energy. A power take-off and damping mechanism is then
25 provided for transforming incoming power, oscillating at
26 a low frequency, into a higher frequency oscillating form
27 for use in a generator, turbine, reverse osmosis plant or
28 the like.

29

30 It is known to those skilled in the art that the systems
31 described above can be increased in efficiency. This can
32 be achieved by incorporating them with double stage
33 filtration systems, sequential filtration systems, and by
34 using the high pressure brine waste output from the

1 filters to drive pumps or pelton wheels for energy
2 recovery.

3

4 Water engines are alternative means known to be suitable
5 for extracting energy from a body of water e.g. UK Patent
6 Application No. 2,138,509 and 2,093,124. In such engines
7 one or more floats are housed within one or more
8 associated water chambers. Input gate valves permit
9 water from the body of water to be admitted to the water
10 chambers and then to be exhausted to a lower level,
11 thereby causing the floats to rise and fall. Power is
12 thereafter harnessed from the floats by means of one or
13 more hydraulic rams that are mechanically connected to
14 the floats within the water chambers. In particular the
15 hydraulic rams use the kinetic energy of the floats to
16 pressurise a hydraulic fluid contained within the
17 hydraulic rams.

18

19 It is an object of aspects of the present invention to
20 provide a desalination device that employs a water engine
21 in order to provide the required power for reverse
22 osmosis of a liquid.

23

24 It is a further object of an aspect of the present
25 invention to provide a desalination device that employs a
26 water engine that operates by extracting tidal energy.

27

28 According to a first aspect of the present invention
29 there is provided a desalination device for desalination
30 of a liquid comprising a water engine suitable for
31 extracting energy from a body of water and a reverse
32 osmosis unit wherein the liquid is initially supplied for
33 use as a hydraulic fluid within one or more hydraulic

1 rams of the water engine before being directed under
2 pressure to the reverse osmosis unit for desalination.

3

4 Most preferably the liquid is extracted directly from the
5 body of water within the water engine.

6

7 Preferably the desalination device further comprises an
8 input filter suitable for removing particulate debris or
9 suspended solids contained within the body of water.

10

11 Preferably the water engine comprises one or more water
12 driven members mechanically connected to the one or more
13 hydraulic rams.

14

15 Preferably the one or more water driven members comprise
16 a float chamber, a float, an input gate valve and an
17 output gate valve.

18

19 Preferably the input gate valve and the output gate valve
20 comprise a butterfly valve.

21

22 Preferably a changing geometry headgear connects the
23 floats of two or more water driven members

24

25 Preferably the changing geometry headgear comprises a
26 pivotally mounted beam.

27

28 Preferably the pivotally mounted beam comprises an
29 extendible post associated with each water driven member
30 wherein the post adjustably connects to the associated
31 float allowing the position of the float to be adjusted
32 relative to the associated float chamber.

33

1 Most preferably the one or more hydraulic rams are
2 connected at one end to the pivotally mounted beam.

3

4 Optionally the desalination device further comprises a
5 device input valve suitable for controlling the liquid
6 supplied to the one or more hydraulic rams.

7

8 Most preferably the one or more hydraulic rams comprise
9 an input port and an output port that move between an
10 open and a closed position so providing means for
11 controlling the flow of the liquid through the one or
12 more hydraulic rams.

13

14 Preferably the position of the input port and the output
15 port are controlled by the movement of the float in the
16 water chamber.

17

18 Preferably the input port and the output port comprise a
19 non return valve.

20

21 Most preferably the reverse osmosis unit comprises a
22 hydraulic accumulator and a first reverse osmosis filter
23 wherein the hydraulic accumulator stores the high
24 pressure liquid output from the one or more hydraulic
25 rams before passing the stored liquid through the first
26 reverse osmosis filter.

27

28 Most preferably the reverse osmosis unit further
29 comprises a second reverse osmosis filter which acts to
30 filter a permeate produced by the first reverse osmosis
31 filter.

32

33 Optionally exhaust liquid from the second reverse osmosis
34 filter is stored within a liquid reservoir so as to

1 provide a second liquid source for the one or more
2 hydraulic rams.

3

4 Preferably the desalination device further comprises an
5 hydraulic motor that is driven by an exhaust liquid from
6 the first reverse osmosis filter.

7

8 Preferably the desalination device further comprises a
9 control valve and double acting hydraulic ram wherein the
10 control valve is powered by the high pressure exhaust
11 liquid from the first reverse osmosis filter so as to
12 operate the double acting hydraulic ram thus providing a
13 means for controlling the input and output gate valves.

14

15 Preferably the control valve comprises a three position
16 four port valve.

17

18 Preferably the desalination device further comprises a
19 low pressure pump wherein the low pressure pump is
20 powered by the hydraulic motor so as to draw the body of
21 water through the input filter thereby supplying the
22 liquid to the one or more hydraulic rams.

23

24 Optionally the desalination device further comprises a
25 high pressure pump wherein the high pressure pump is
26 powered by the hydraulic motor so as to draw the body of
27 water through the input filter thereby providing a second
28 high pressure liquid supply to the hydraulic accumulator.

29

30 Preferably the desalination device further comprises an
31 electrical generator and a rechargeable battery wherein
32 the electrical generator is driven by the exhaust liquid
33 from the first reverse osmosis filter so as to charge the
34 rechargeable battery.

1
2 Optionally the desalination device further comprises one
3 or more diagnostics for monitoring the operation of the
4 device.

5
6 Preferably the rechargeable battery source provides the
7 required power for the one or more diagnostics.

8
9 According to a second aspect of the present invention
10 there is provided a method of desalinating a liquid
11 wherein the method comprises the steps of:

- 12 1) Deploying a water engine and a reverse osmosis
13 unit within a body of water;
- 14 2) Supplying the liquid for desalination to one or
15 more hydraulic rams of the water engine;
- 16 3) Extracting the energy associated with the body of
17 water so as to power the water engine such that
18 the liquid supplied to the hydraulic rams is
19 pressurised; and
- 20 4) Supplying the pressurised liquid for desalination
21 by the reverse osmosis unit.

22
23 Preferably the step of deploying the water engine and the
24 reverse osmosis unit within the body of water comprises
25 locating the water engine and the reverse osmosis unit
26 within an enclosed reservoir provided with a means for
27 controllably releasing the enclosed water of the
28 reservoir. Alternatively, the step comprises locating
29 the water engine and the reverse osmosis unit within a
30 stream, river or other similar naturally occurring moving
31 body of water.

32

1 Most preferably the step of supplying the liquid for
2 desalination comprises the step of redirecting a sample
3 of the body of water to the one or more hydraulic rams.

4

5 Preferably the step of supplying the liquid for
6 desalination further comprises the systematic opening and
7 closing of one or more input ports and one or more output
8 ports so as to regulate the flow of the liquid through
9 the one or more hydraulic rams.

10

11 Optionally the systematic opening and closing of the one
12 or more input ports and the one or more output ports is
13 controlled by changes in pressure within the one or more
14 hydraulic rams caused by the movement of one or more
15 floats within the water engine.

16

17 Preferably the step of extracting the energy associated
18 with the body of water comprises the systematic opening
19 and closing of one or more input gate valves and one or
20 more output gate valves so as to regulate the flow of the
21 body of water through the water engine.

22

23 Most preferably the desalination by the reverse osmosis
24 unit comprises the following steps:

25 1) Passing the pressurised liquid through a first
26 osmosis filter so as to produce a first filter
27 permeate and a first filter exhaust;

28 2) Passing the first filter permeate through a second
29 reverse osmosis filter so as to produce an output
30 permeate and a second filter exhaust;

31

32 Optionally energy within the first filter exhaust is
33 harnessed to improve the efficiency of the method of
34 desalinating the liquid.

1
2 Most preferably the first filter exhaust exits the
3 reverse osmosis unit at a location physically separated
4 from the supply of liquid for desalination.

5
6 Most preferably the second filter exhaust is directed to
7 a reservoir for recycling into the one or more hydraulic
8 rams.

9
10 Embodiments of the invention will now be described, by
11 way of example only, with reference to the accompanying
12 drawings, in which:

13
14 Figure 1 present a schematic representation of a
15 desalination device in accordance with an
16 aspect of the present invention;

17 Figure 2 presents a schematic representation of a water
18 engine employed by the desalination device;

19 Figure 3 present a circuit diagram of the desalination
20 device of Figure 1; and

21 Figure 4 presents an illustration showing the
22 operational time periods for the desalination
23 device of Figure 1.

24
25 Figure 1 presents a schematic representation of a
26 desalination device 1 in accordance with an aspect of the
27 present invention. The desalination device 1 can be seen
28 to comprise three main components namely, an input filter
29 2, a water engine 3 and a reverse osmosis unit 4.
30 Generally the device 1 operates by passing sea water
31 through the input filter 2 which removes particulate
32 debris and suspended solids. The water engine 3 then
33 pumps the sea water to a high pressure sufficient for it

1 to pass through the reverse osmosis filter unit 4 thus
2 producing water suitable for human consumption.

3

4 The water engine 3 typically is of a type taught of in UK
5 Patent No. GB 2,138,509, a schematic representation of
6 which is shown in Figure 2. The water engine 3 can be
7 seen to comprise two floats 5 arranged to reciprocate
8 vertically in respective water chambers 6. Water is
9 admitted and expelled from each chamber 6 via gate valves
10 7. In particular water is drawn from a head of water
11 into the water engine 3 before being allowed to exhaust
12 to a lower level (details of this process are described
13 below). This process causes the floats 5 to rise and
14 fall thus acting to drive a pivotally mounted beam 8.

15

16 The water engine 3 is adapted and improved in order to
17 make it suitable for use with a water reservoir energy
18 source. In the first instance the floats 5 are adapted
19 so as to be capable of moving up in response to the
20 rising water levels associated with a flood tide.
21 Similarly, the floats can move down as the mean water
22 level falls as experienced during ebb tides. This is
23 adjustment is realised by mounting the floats 5 on
24 extensible posts 9 using threaded adjusters so as to
25 provide a facility for moving the floats 5 up or down on
26 the posts 9 as the average level of the water changes
27 during an operating period. The adjusters may be driven
28 by hydraulic or electrical motors under the control of a
29 central control unit, in response to changes of the
30 reservoir and external water levels.

31

32 In place of a closed circuit hydraulic system previously
33 used to extract power from the water engine 3, two
34 hydraulic rams 10 and 11 have been adapted so as to pump

1 sea water to a high pressure. The hydraulic rams 10 and
2 11 do not employ hydraulic oil but instead are supplied
3 with sea water at their input. Compression of a
4 hydraulic ram 10 or 11 results in the sea water being
5 compressed to a pressure of around 84 bar (84×10^5 Pa)
6 suitable for input to the reverse osmosis unit 4.
7 Additionally, the supply of water to the hydraulic rams
8 10 and 11 is filtered by filter 2 so as to remove
9 suspended solids, sand and other contaminants.

10

11 A circuit diagram of a particular embodiment of the
12 desalination device 1 is shown in Figure 3. For the sake
13 of clarity pressure regulation valves, control valves,
14 isolation valves and pressure gauges are not shown
15 throughout the diagram. It will be appreciated that
16 there are many ways of configuring the desalination
17 device 1. However, in this embodiment the device is
18 deployed such that the water engine 3 interacts with a
19 sea water reservoir.

20

21 Initially the sea water is drawn through the filter 12
22 via a low pressure pump 22 or through a first non return
23 valve 13. The hydraulic rams 10 and 11 are then driven
24 by the movement of the floats 5 of the water engine 3 as
25 described in UK Patent No. GB 2,138,509. The hydraulic
26 rams 10 and 11 are arranged so as to move in opposite
27 directions. Thus, when hydraulic ram 10 is on its
28 extension stroke it draws sea water in through a first
29 input non return valve 14 while a corresponding first
30 output non return valve 15 is closed.

31

32 Hydraulic ram 11 then forces the fluid in its body out
33 through a second output non return valve 17 while a
34 second input non return valve 16 remains closed. On the

1 opposite stroke of the floats 5 of the water engine 3
2 hydraulic ram 11 is on its extension stroke drawing sea
3 water in through the second input non return valve 16
4 while second output non return valve 17 is closed.
5 Hydraulic ram 10, on its compression stroke, forces the
6 fluid in its body out through the first output non return
7 valve 15 while the first input non return valve 14
8 remains closed.

9
10 The output from the hydraulic rams is then fed to a
11 hydraulic accumulator 30 that maintains a steady pressure
12 in the system of around 84 bar (84×10^5 Pa). This high
13 pressure water source then feeds the first reverse
14 osmosis filter 18 that comprises a polyamide membrane. A
15 suitable example is Osmonics 414-SW2(PA). Reverse
16 osmosis filter 18 permits some 25% of the water to pass
17 into to pipe 27 as permeate. The remaining 75% of Brine
18 or more concentrated sea water is ejected out at pipe 26.

19
20 The high pressure water in pipe 26 is then fed to a motor
21 20 and a control valve 24 system. The control valve 24
22 is a three position four port control valve for a double
23 acting hydraulic ram 25, which serves to drive the water
24 engine gate valves 7, that alternately admit or release
25 water from the water chambers, as described in detail in
26 UK Patent No. GB 2,138,509. The operation of valve 24
27 can be either electrical, via a central control unit, or
28 mechanical and its operation is triggered by the floats 5
29 of the water engine 3 reaching the ends or near the ends
30 of their strokes. The valve 24 also allows the water
31 engine 3 to be stopped by positioning the valve 24 in the
32 central isolation position. In this position the gate
33 valves are all open allowing the water engine to operate
34 as a sluice.

1

2 The waste water ejected from the hydraulic ram 25 through
3 valve 24 is returned to the sea away from the inlet to
4 filter 12 so as to avoid the problematic feature of Prior
5 Art systems whereby the salt concentration of the water
6 input to the system can be inadvertently increased.

7

8 Hydraulic motor 20 is employed to recover energy from the
9 high pressure water ejected as concentrate from reverse
10 osmosis filter 18. High pressure water in pipe 26 drives
11 motor 20 that in turn drives an electrical generator 21,
12 the low pressure pump 22 and the high pressure pump 31.
13 The waste brine from the motor 20 is again expelled from
14 the device at a point physically separated from the inlet
15 filter 12.

16

17 Low pressure pump 22 can then be used to aid the drawing
18 of water in through filter 2 as well as providing a
19 secondary pressurised input to the hydraulic rams 10 and
20 11 of some 1 bar (1×10^5 Pa). This secondary pressure
21 input is particularly useful in overcoming the water
22 engines lack of force at the end of each stroke when the
23 hydraulic rams 10 and 11 are proving the maximum input
24 suction. Such characteristics have been problematic in
25 systems described in the Prior Art resulting in an
26 overall reduced working efficiency of those devices.
27 Hydraulic reservoir 29 accumulates this low pressure
28 input to provide a constant supply over the cyclical
29 demands of the hydraulic rams.

30

31 High pressure pump 31 draws sea water through the input
32 filter 2 and pumps it to some 84 bar (84×10^5 Pa). This
33 high pressure sea water is fed to hydraulic accumulator
34 30 for input to the first reverse osmosis filter 18.

1
2 Generator 21 is used to generate electricity for charging
3 batteries that drive a control system and diagnostics
4 that monitors and controls the operation of the
5 desalination device 1. In times of lower demand for water
6 output the use of a larger generator allows provision of
7 electrical power for a remote area. Conventional control
8 techniques known to those skilled in the art are used for
9 this purpose.

10
11 The permeate output of reverse osmosis filter 18 is fed
12 into a second reverse osmosis filter 19 via a pipe 27.
13 Thus the desalination device effectively employs a two
14 pass reverse osmosis system. Reverse osmosis filter 19
15 comprises a Cellulose Acetate type with an operating
16 pressure of some 22.5 bar (22.5×10^5 Pa). A suitable
17 example is Osmonics 411-PR. The output permeate is then
18 fed by pipe to the required location, for example an on
19 shore water storage facility.

20
21 To further increase the system efficiency the rejected
22 concentrate from reverse osmosis filter 19 is fed by pipe
23 28 via a non return valve 23 to the input of the main
24 hydraulic rams and is stored in a water reservoir 29.
25 This helps to recover some of the lower pressure energy
26 from the input to reverse osmosis filter 19. Optionally
27 a further energy extraction mechanism can be fitted at
28 this point. A secondary advantage of re routing this
29 rejected sea water is that the salt concentration is
30 still much less than that of the original sea water as it
31 has already passed through reverse osmosis filter 18.
32 Therefore the salt concentration in the sea water fed
33 back through the desalination device is reduced.

34

1 It should be noted that if there is no pressure in water
2 reservoir 29 and low-pressure pump 22 is not operating
3 the suction of the hydraulic rams via the input non
4 return valves 14 and 16 draws sea water in through the
5 first non return valve 13 and filter 2. This results in
6 slower cycling of the water engine as the water engine
7 does not generate as much force at the end of each
8 stroke. However, pressurising the inputs to the
9 hydraulic rams results in faster water engine cycling and
10 improved throughput, thus improving the performance of
11 the water engine as described in UK Patent No. GB
12 2,138,509.

13

14 By using a two pass reverse osmosis system the salt
15 rejection required by reverse osmosis filter 18 can be as
16 low as 95%, compared with 99% required for a single pass
17 system. In addition the second reverse osmosis filter 19
18 can then be a cheaper and more effective brackish water
19 model.

20

21 The desalination device 1 is ideal for use in conjunction
22 with a tidal barrage (not shown) that is capable of
23 capturing an area of tidal water to shore. The tidal
24 barrage typically comprises sluice gates that can be
25 moved between an open and closed position. For a tidal
26 range of typically 5m mean rise and fall the water
27 engine 3 operating from a head of 1.5m would permit
28 operation of the desalination device 1 for some 4 hours
29 out of 6 hours on the ebb of the tide and some 4 hours
30 out of 6 hours on the flood tide.

31

32 The energy stored in the hydraulic accumulator 30 is used
33 to allow the gate valves 7 to be operated to restart the
34 water engine, or to perform a sluicing operation between

1 tides. For instance when the water head becomes
2 insufficient sluicing ~~via the desalination device~~ is
3 employed so as to allow the area enclosed by the tidal
4 barrage to be either almost fully emptied (ebb tide) or
5 almost fully filled (flood tide).

6
7 Figure 4 illustrates the operating periods of the system
8 using double tide working over a complete tidal cycle.
9 At the start of the cycle 40 the tide is fully in and the
10 tidal basin water level is almost equal to that of the
11 outside sea. The sluice gates are closed and the water
12 engine is not operating and the gate valves 7 are shut in
13 one direction. After a period of time the sea level
14 outside the basin falls to cause a differential head of
15 water across the tidal barrage and the water engine 3.
16 At 41 the head is sufficient for the water engine 3 to
17 commence efficient operation and therefore the water
18 engine 3 is started by enabling the float controlled
19 operation of the gate valves 7. The operation of the
20 water engine 3 then pumps the sea water as described
21 above.

22
23 As the water engine 3 passes water through the water
24 chambers 6 the water in the tidal basin 42 falls at the
25 same rate as the outside sea. At the end of the ebb tide
26 power extraction phase 43 the operating head starts to
27 fall and the water engine 3 is disabled.

28
29 To prepare for the next cycle the water engine 3 can be
30 switched to sluicing mode and or additional sluice gates
31 in the tidal barrage opened. Here the larger the sluice
32 gates are made the nearer the tidal basin level will
33 approach that of the sea during sluicing. The ebb tide

1 sluicing stops at low water 44 and the gate valves 7 are
2 closed along with any additional sluice gates.

3

4 After a period of time the sea level outside the tidal
5 barrage has risen to provide the required operating head
6 45 and the water engine 3 is again started. As the tide
7 rises 46 the basin water level also rises with the water
8 flowing through the operating desalination device 1.
9 Towards the end of the flood tide the operating head
10 starts to fall 47 and the system again switches to
11 sluicing allowing the basin water level to rise until
12 high water is reached 48. At this point the sluice gates
13 are closed and the complete cycle starts again.

14

15 In an alternative embodiment the desalination device can
16 be adapted such that it operates on a single tide
17 although such an arrangement would reduce the power
18 output periods in comparison with the double tide
19 embodiment.

20

21 Aspects of the present invention describe a desalination
22 device that operates using tidal energy. A significant
23 advantage of such a system is the saving in running costs
24 associated with providing the power needed in the Prior
25 Art systems for pumping the water. Additionally, as
26 there is no need to install an electricity supply or
27 other generation means to provide the power for
28 desalination this can lead to significant cost savings,
29 and the ability to provide water supplies in otherwise
30 impractical conditions.

31

32 The desalination device described has the further
33 advantage that it employs simple technology and therefore
34 provides for low maintenance reliable installations. By

1 using a two pass reverse osmosis system the lifetime of
2 the filter elements can also be extended and therefore a
3 lower maintenance more robust reverse osmosis process is
4 produced.

5

6 The desalination device is ideal for installation with an
7 in shore sited barrage that allows for easy access and
8 easy transportation of the output water by pipe to a
9 shore based storage facility. The device is also fully
10 scaleable such that a suitably sized system can be
11 installed in an existing location, for example at the
12 mouth of a disused harbour, or in a short barrage across
13 a narrow inlet.

14

15 By using the tide as the power source a continual supply
16 of fresh water can be realised, with gaps limited only to
17 the high and low periods of the tide. As a result the
18 fresh water supply is not affected by weather conditions,
19 which might affect other renewable energy sources, or a
20 rainfall based water supply system. Such features
21 minimise the need for large fresh water storage systems
22 that may not be easily realised on an island location.

23

24 Employing the hydraulic rams to directly pump sea water
25 has the added advantage that it avoids the use of
26 hydraulic oil. Therefore, there are obvious advantages
27 to the environment in that the risk of contamination is
28 significantly reduced.

29

30 The use of the output of the hydraulic rams allows the
31 desalination device to operate at low heads of water thus
32 making it suitable for double tide working. This
33 provides for a very efficient use of the tidal energy
34 available as it minimises the losses associated with the

1 Prior Art water engines in translating tidal energy into
2 electrical power and back again into mechanical power.
3 By using existing technique for energy recovery in
4 reverse osmosis processing combined with a small
5 electrical generator to power the process control and
6 monitoring equipment the use of the available energy can
7 be optimised.

8

9 As the desalination device works on a doubled tide mode
10 there would be little impact on the local environment as
11 the water inside the breakwater would still rise and fall
12 like the tide, albeit slightly delayed in phase.

13

14 The desalination device can be used for water
15 purification in a run of river situation by installing
16 the device across a weir or small dam in the river to
17 generate the necessary head for operation. In this
18 installation a different form of reverse osmosis system
19 may be used to more efficiently purify the river water.
20 The run of river provides the energy source to drive the
21 desalination device in this instance.

22

23 The foregoing description of the invention has been
24 presented for purposes of illustration and description
25 and is not intended to be exhaustive or to limit the
26 invention to the precise form disclosed. The described
27 embodiments were chosen and described in order to best
28 explain the principles of the invention and its practical
29 application to thereby enable others skilled in the art
30 to best utilise the invention in various embodiments and
31 with various modifications as are suited to the
32 particular use contemplated. Therefore, further
33 modifications or improvements may be incorporated without

- 1 departing from the scope of the invention as defined by
- 2 the appended claims. ———

1 CLAIMS

2

3 1) A desalination device for desalination of a liquid
4 comprising a water engine suitable for extracting
5 energy from a body of water and a reverse osmosis
6 unit wherein the liquid is initially supplied for use
7 as a hydraulic fluid within one or more hydraulic
8 rams of the water engine before being directed under
9 pressure to the reverse osmosis unit for
10 desalination.

11

12 2) A desalination device as claimed in Claim 1 wherein
13 the liquid is extracted directly from the body of
14 water within the water engine.

15

16 3) A desalination device as claimed in Claim 1 or 2
17 further comprising an input filter suitable for
18 removing particulate debris or suspended solids
19 contained within the body of water.

20

21 4) A desalination device as claimed in any of the
22 preceding Claims wherein the water engine comprises
23 one or more water driven members mechanically
24 connected to the one or more hydraulic rams.

25

26 5) A desalination device as claimed in Claim 4 wherein
27 the one or more water driven members comprise a float
28 chamber, a float, an input gate valve and an output
29 gate valve.

30

31 6) A desalination device as claimed in Claim 5 wherein
32 the input gate valve and the output gate valve
33 comprise a butterfly valve.

34

- 1 7) A desalination device as claimed in Claim 5 or 6
2 wherein a changing geometry headgear connects the
3 floats of two or more water driven members.
4
- 5 8) A desalination device as claimed in Claim 7 wherein
6 the changing geometry headgear comprises a pivotally
7 mounted beam.
8
- 9 9) A desalination device as claimed in Claim 8 wherein
10 the pivotally mounted beam comprises an extendible
11 post associated with each water driven member such
12 that the post adjustably connects to the associated
13 float allowing the position of the float to be
14 adjusted relative to the associated float chamber.
15
- 16 10) A desalination device as claimed in Claim 8 or 9
17 wherein the one or more hydraulic rams are connected
18 at one end to the pivotally mounted beam.
19
- 20 11) A desalination device as claimed in any of the
21 preceding Claims wherein the desalination device
22 further comprises a device input valve suitable for
23 controlling the liquid supplied to the one or more
24 hydraulic rams.
25
- 26 12) A desalination device as claimed in any of the
27 preceding Claims wherein the one or more hydraulic
28 rams comprise an input port and an output port that
29 move between an open and a closed position so
30 providing means for controlling the flow of the
31 liquid through the one or more hydraulic rams.
32
- 33 13) A desalination device as claimed in Claim 12 wherein
34 the position of the input port and the output port

1 are controlled by the movement of the float in the
2 water chamber.

3

4 14) A desalination device as claimed in Claim 12 or 13
5 wherein the input port and the output port comprise a
6 non return valve.

7

8 15) A desalination device as claimed in any of the
9 preceding Claims wherein the reverse osmosis unit
10 comprises a hydraulic accumulator and a first reverse
11 osmosis filter wherein the hydraulic accumulator
12 stores the high pressure liquid output from the one
13 or more hydraulic rams before passing the stored
14 liquid through the first reverse osmosis filter.

15

16 16) A desalination device as claimed in Claim 15 wherein
17 the reverse osmosis unit further comprises a second
18 reverse osmosis filter which acts to filter a
19 permeate produced by the first reverse osmosis
20 filter.

21

22 17) A desalination device as claimed in Claim 16 wherein
23 an exhaust liquid from the second reverse osmosis
24 filter is stored within a liquid reservoir so as to
25 provide a second liquid source for the one or more
26 hydraulic rams.

27

28 18) A desalination device as claimed in any of the
29 preceding Claims wherein the desalination device
30 further comprises an hydraulic motor that is driven
31 by an exhaust liquid from the first reverse osmosis
32 filter.

33

1 19) A desalination device as claimed in Claim 18 wherein
2 ~~the desalination device further comprises a control~~
3 valve and double acting hydraulic ram wherein the
4 control valve is powered by the exhaust liquid from
5 the first reverse osmosis filter so as to operate the
6 double acting hydraulic ram thus providing a means
7 for controlling the input and output gate valves.
8

9 20) A desalination device as claimed in Claim 19 wherein
10 the control valve comprises a three position four
11 port valve.
12

13 21) A desalination device as claimed in Claim 3 to 20
14 wherein the desalination device further comprises a
15 low pressure pump, the low pressure pump being
16 powered by the hydraulic motor so as to draw the body
17 of water through the input filter thereby supplying
18 the liquid to the one or more hydraulic rams.
19

20 22) A desalination device as claimed in Claim 15 to 21
21 wherein the desalination device further a high
22 pressure pump, the high pressure pump being powered
23 by the hydraulic motor so as to draw the body of
24 water through the input filter thereby providing a
25 second high pressure liquid supply to the hydraulic
26 accumulator.
27

28 23) A desalination device as claimed in Claim 22 wherein
29 the desalination device further comprises an
30 electrical generator and a rechargeable battery, the
31 electrical generator being driven by the exhaust
32 liquid from the first reverse osmosis filter so as to
33 charge the rechargeable battery.
34

1

2 24) A desalination--device-- as claimed in any of the
3 preceding Claims wherein the desalination device
4 further comprises one or more diagnostics for
5 monitoring the operation of the device.

6

7 25) A desalination device as claimed in Claim 24 wherein
8 the rechargeable battery source provides the required
9 power for the one or more diagnostics.

10

11 26) A method of desalinating a liquid the method
12 comprising the steps of:

- 13 1) Deploying a water engine and a reverse osmosis
14 unit within a body of water;
15 2) Supplying the liquid for desalination to one or
16 more hydraulic rams of the water engine;
17 3) Extracting the energy associated with the body of
18 water so as to power the water engine such that
19 the liquid supplied to the hydraulic rams is
20 pressurised; and
21 4) Supplying the pressurised liquid for desalination
22 by the reverse osmosis unit.

23

24 27) A method of desalinating a liquid as claimed in
25 Claim 26 wherein the step of deploying the water
26 engine and the reverse osmosis unit within the body
27 of water comprises locating the water engine and the
28 reverse osmosis unit within an enclosed reservoir
29 provided with a means for controllably releasing the
30 enclosed water of the reservoir.

31

32 28) A method of desalinating a liquid as claimed in
33 Claim 26 wherein the step of deploying the water
34 engine and the reverse osmosis unit within the body

1 of water comprises locating the water engine and the
2 reverse osmosis unit within a stream, river or other
3 similar naturally occurring moving body of water.
4

5 29) A method of desalinating a liquid as claimed in
6 Claim 26 to 28 wherein the supply of the liquid for
7 desalination comprises redirecting a sample of the
8 body of water to the one or more hydraulic rams.
9

10 30) A method of desalinating a liquid as claimed in
11 Claim 26 to 29 wherein the supply of the liquid for
12 desalination comprises the systematic opening and
13 closing of one or more input ports and one or more
14 output ports so as to regulate the flow of the liquid
15 through the one or more hydraulic rams.
16

17 31) A method of desalinating a liquid as claimed in
18 Claim 30 wherein the systematic opening and closing
19 of the one or more input ports and the one or more
20 output ports is controlled by changes in pressure
21 within the one or more hydraulic rams caused by the
22 movement of one or more floats within the water
23 engine.
24

25 32) A method of desalinating a liquid as claimed in
26 Claim 26 to 31 wherein the extraction of the energy
27 associated with the body of water comprises the
28 systematic opening and closing of one or more input
29 gate valves and one or more output gate valves so as
30 to regulate the flow of the body of water through the
31 water engine.
32

1 33) A method of desalinating a liquid as claimed in
2 Claim 26 to 32 wherein the desalination by the
3 reverse osmosis unit comprises the following steps:

4 1) Passing the pressurised liquid through a first
5 osmosis filter so as to produce a first filter
6 permeate and a first filter exhaust;

7 2) Passing the first filter permeate through a second
8 reverse osmosis filter so as to produce an output
9 permeate and a second filter exhaust;

10

11 34) A method of desalinating a liquid as claimed in
12 Claim 33 wherein energy within the first filter
13 exhaust is harnessed to improve the efficiency of the
14 method of desalinating the liquid.

15

16 35) A method of desalinating a liquid as claimed in
17 Claim 33 or 34 wherein the first filter exhaust exits
18 the reverse osmosis unit at a location physically
19 separated from the supply of liquid for desalination.

20

21 36) A method of desalinating a liquid as claimed in
22 Claim 33 to 34 wherein the second filter exhaust is
23 directed to a reservoir for recycling into the one or
24 more hydraulic rams.

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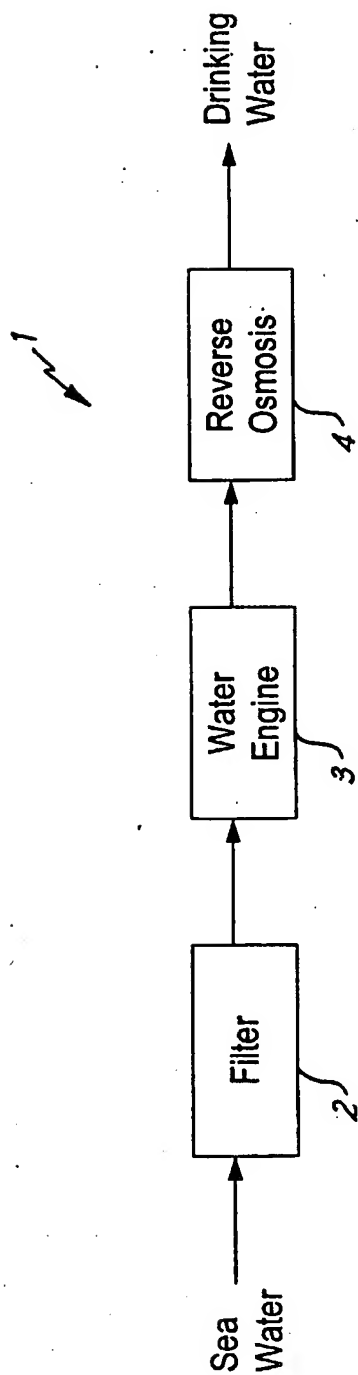
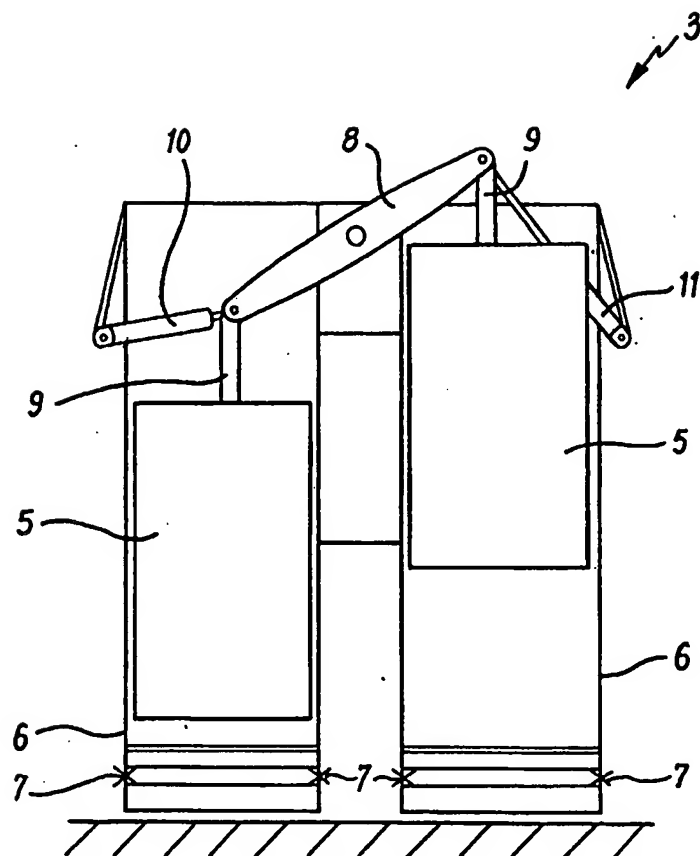
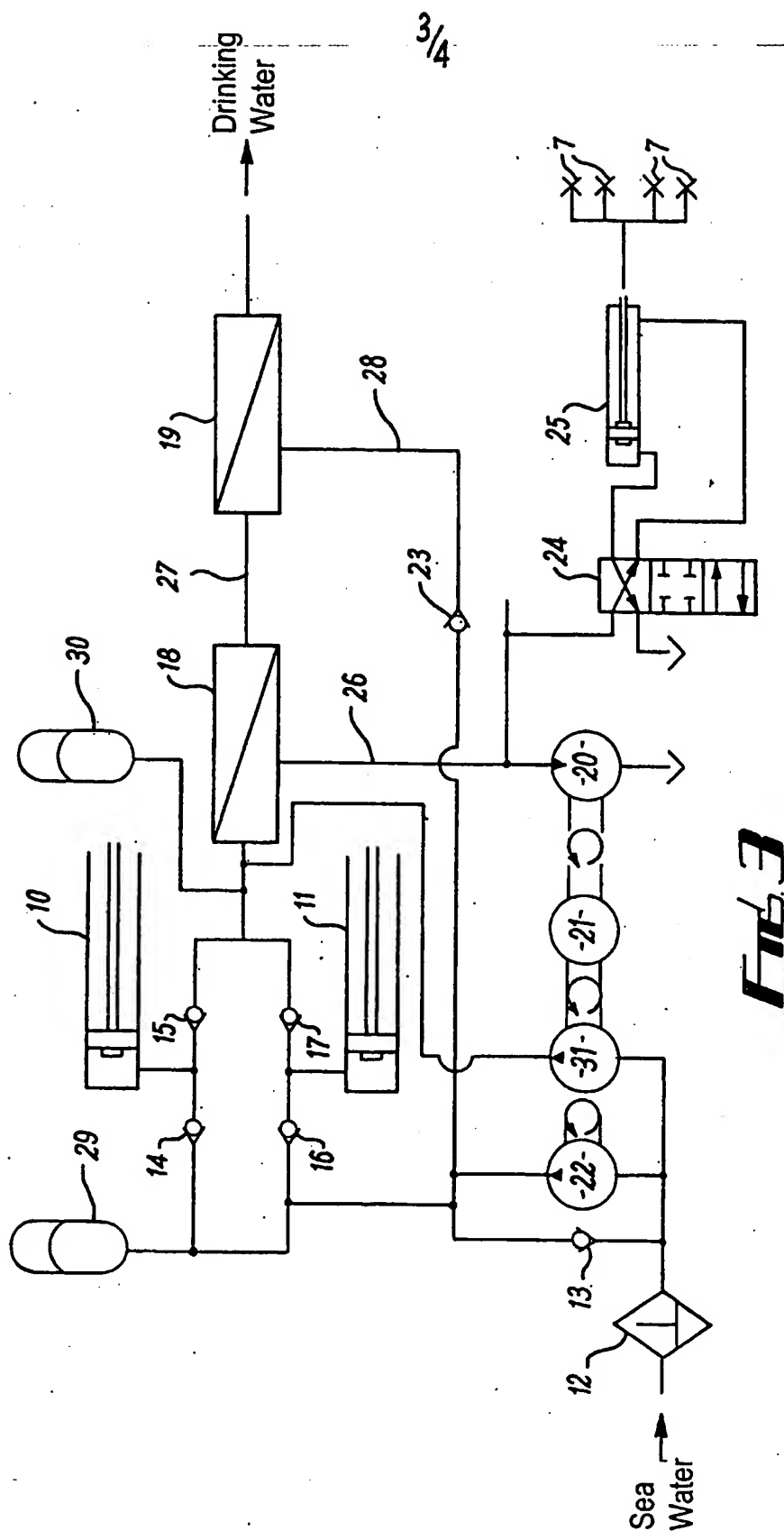
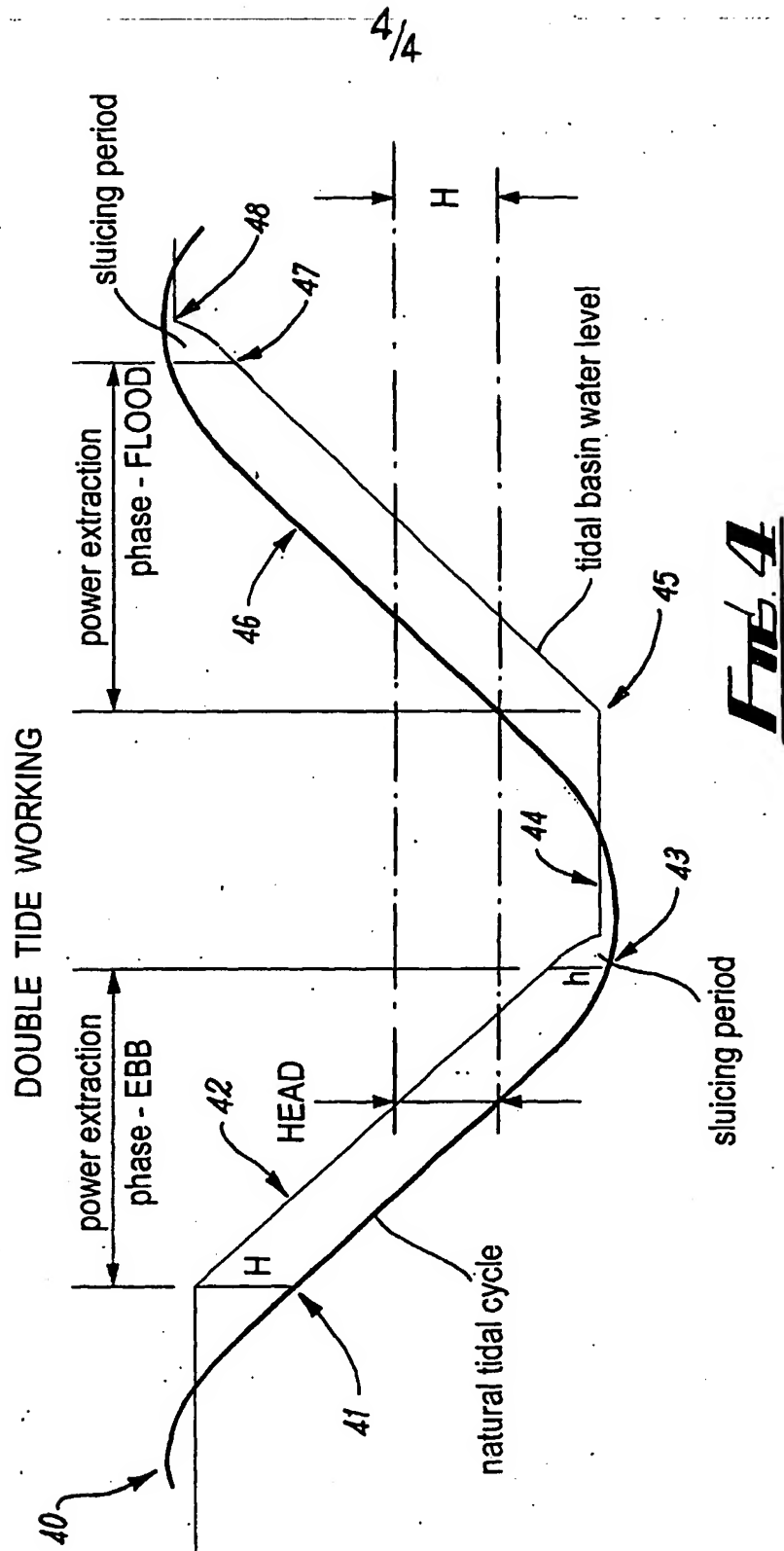


Fig. 1

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**FIG. 2**





INTERNATIONAL SEARCH REPORT

Inte rnational Application No

PCT7GB 03/04956

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B01D61/10 F03B13/26 F03B17/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B01D F03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DATABASE WPI Section Ch, Week 199801 Derwent Publications Ltd., London, GB; Class D15, AN 1998-002228 XP002276778 -& ES 2 107 384 A (UNIV ALCALA DE HENARES) , 16 November 1997 (1997-11-16) abstract	1,2,4, 26,28,29
A	---	3,15,16, 18,33-35
	--- -/--	

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Inte nal Application No

PCT/GB 03/04956

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 698 969 A (LEE JIIN-JEN ET AL) 13 October 1987 (1987-10-13) abstract; figures 1-8,20 column 1, line 52 -column 2, line 36 column 7, line 3 - line 64 column 10, line 10 - line 46	1,2,4, 26,28,29
A		3,15,16, 18,33-35
X	US 5 186 822 A (TZONG TSAIR-JYH ET AL) 16 February 1993 (1993-02-16) the whole document	1-4,15, 16,26, 28,29, 33,35
X	US 5 411 377 A (HOUSER MICHAEL P ET AL) 2 May 1995 (1995-05-02) abstract; figures column 1, line 61 -column 2, line 7 column 4, line 11 -column 6, line 60	1,3,4, 18,26, 28,29
A		34
X	EP 0 059 275 A (SEAGOLD IND CORP) 8 September 1982 (1982-09-08) abstract; figures 1,6 page 31, line 6 -page 33, line 7	1,3,4, 15,26, 28,29
A		35
A	GB 2 138 509 A (AUR HYDROPOWER LTD) 24 October 1984 (1984-10-24) cited in the application the whole document	1,4-14, 19,26, 30-32
A	GB 2 093 124 A (AUR HYDROPOWER LTD) 25 August 1982 (1982-08-25) cited in the application the whole document	1,4-14, 19,26, 30-32
A	EP 1 197 658 A (BONET SUBIRANA PERE ;BONET ALMEDA PEDRO (ES)) 17 April 2002 (2002-04-17) the whole document	1,2,4, 26,28,29
A	GB 1 130 107 A (ARTHUR PAUL PEDRICK) 9 October 1968 (1968-10-09) cited in the application the whole document	1,2,26, 28
P,X	WO 03/087569 A (LUNATECH LLC) 23 October 2003 (2003-10-23) the whole document	1-4,26, 28,29

INTERNATIONAL SEARCH REPORT..

Information on patent family members

International Application No

PCT/GB 03/04956

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
ES 2107384	A	16-11-1997	ES 2107384 A1	16-11-1997
US 4698969	A	13-10-1987	US 4594853 A	17-06-1986
			AU 4067685 A	11-10-1985
			BE 901920 A1	12-09-1985
			BR 8506044 A	25-03-1986
			DE 3590110 T	24-04-1986
			DK 516685 A	08-11-1985
			ES 8706340 A1	01-09-1987
			FI 854427 A	11-11-1985
			FR 2560936 A1	13-09-1985
			GB 2166498 A ,B	08-05-1986
			JP 61502623 T	13-11-1986
			NL 8520054 T	03-02-1986
			NO 854481 A	11-11-1985
			NZ 211411 A	30-09-1987
			PH 21763 A	18-02-1988
			PT 80088 A ,B	01-04-1985
			SE 8505310 A	11-11-1985
			WO 8504219 A1	26-09-1985
			ZA 8501823 A	30-10-1985
US 5186822	A	16-02-1993	NONE	
US 5411377	A	02-05-1995	WO 9623973 A1	08-08-1996
			AU 1831695 A	21-08-1996
EP 0059275	A	08-09-1982	AU 552382 B2	29-05-1986
			AU 6759081 A	27-08-1981
			CA 1176572 A1	23-10-1984
			EP 0059275 A1	08-09-1982
			JP 56150405 A	20-11-1981
GB 2138509	A	24-10-1984	AT 35846 T	15-08-1988
			BR 8400872 A	02-10-1984
			CA 1229774 A1	01-12-1987
			DE 3472820 D1	25-08-1988
			EP 0117739 A2	05-09-1984
			GR 79995 A1	31-10-1984
			IE 54985 B1	11-04-1990
			IN 160334 A1	04-07-1987
			JP 59196978 A	08-11-1984
			KR 9208188 B1	25-09-1992
			MX 159542 A	29-06-1989
			NZ 207271 A	08-11-1985
			PH 22197 A	28-06-1988
			US 4691514 A	08-09-1987
			ZA 8401432 A	31-10-1984
GB 2093124	A	25-08-1982	AR 227224 A1	30-09-1982
			AT 13335 T	15-06-1985
			AU 8017082 A	18-08-1983
			BR 8200711 A	21-12-1982
			CA 1182030 A1	05-02-1985
			DD 211388 A5	11-07-1984
			DE 3263478 D1	20-06-1985
			EP 0058542 A1	25-08-1982
			GR 74786 A1	12-07-1984

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 03/04956

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
GB 2093124	A		IE 52464 B1	11-11-1987
			IN 157480 A1	05-04-1986
			JP 57151076 A	18-09-1982
			NL 8200545 A	01-09-1982
			NZ 199625 A	11-10-1985
			OA 7027 A	31-12-1983
			PH 19769 A	27-06-1986
			RO 83448 A1	21-02-1984
			TR 22142 A	12-06-1986
			US 4586333 A	06-05-1986
			ZA 8200739 A	27-10-1982
			ZW 2382 A1	31-08-1983
EP 1197658	A	17-04-2002	ES 2161192 A1	16-11-2001
			AU 4253701 A	08-10-2001
			EP 1197658 A1	17-04-2002
			WO 0173290 A1	04-10-2001
GB 1130107	A	09-10-1968	NONE	
WO 03087569	A	23-10-2003	WO 03087569 A1	23-10-2003
			US 2003189000 A1	09-10-2003